STUDIES IN THE OSTEOLOGY

OF

THE HUMAN FOETUS AND INFANT

being an investigation into the length of the long bones of the Skeleton at different ages, and into the special characters which they present.

BY

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The investigation which has led to the results herein described was commenced with a view to determine merely the relative lengths of the long bones of the human fœtus at different stages of its development. For this purpose a considerable number of specimens was collected together and measurements were taken, but, while examining the bones my attention was struck by certain constant peculiarities in the shape of several of the bones, especially about the articular ends of these of the lower extremity, features which are not present, as a rule, in the European adult but some of which are known to be present in the skeletons of the lower races of mankind, or of prehistoric man, and in apes.

The bones were not models in miniature of the adult structures, but presented certain uniform and well-marked features which were present to a greater or less extent through the whole series.

Recent observations by Fehling and Thompson on the sex characters of the fœtal pelvis suggested to me that this line of observation might be extended to the long bones, in order to determine whether any sex character could be found in them at an earlier

earlier stage than has hitherto been supposed to be the case.

The whole subject seemed to have received only a small amount of attention, but from my observations, I feel convinced that the whole anatomy of the fœtus is worthy of careful examination and comparison with the lower races of mankind and with the higher apes. The "Recapitulation" theory of development makes investigations in this direction of extreme interest.

In connection with this my attention was attracted to certain observations on "The development of the skeleton of the limbs of the Horse, with observations on Polydactyly," by Professor J. Cossar Ewart, in which it is pointed out that there "is a certain amount of resemblance between horse-embryo and the so-called fossil horses," and that the "horse embryo sufficiently resembles them to justify the assumption that they are genetically related."

The small number of references to this subject in all the works on Anatomy indicates that while the processes of ossification and the date of appearance of the different centres of ossification have been carefully investigated, the consideration of the bones

bones of the fœtus from an anthropological standpoint has been almost entirely neglected, and some of the statements made as to the length and character of the bones stand in need of revision.

From a medico-legal point of aspect, the length of the limbs at different periods of intra-uterine life has been collected, but unfortunately for purposes of comparison, the statements are usually made about the length of the entire upper or lower limbs and not of the individual bones.

For this reason, the careful and complete statistics by M. Sue and published in the "Memoires de l'Academie Royale des Sciences" Paris 1775, are practically value -less for comparison.

The pelvis and the cranium of the fœtus have attracted a good deal of attention, and the work by Turner and by Cunningham on the Lumbar Curve has demonstrated characteristics in bones of the fœtus not present in the adult, though present in lower races and in some anthropoids, and now the examination of the skeleton of the lower limb has revealed certain further changes which take place after birth in response to the requirements of the erect attitude assumed gradually

gradually by the child.

I have therefore taken up the three different considerations:-

(1) Rate of Growth of the different long bones.

(2) Their Relative Lengths at different ages.

(3) Characters distinctive of the fœtal as distinguished from the adult bones.

The material used in this investigation consisted of a number of fœti of different ages and sex from the sixth week onwards. In all, thirty sets of limbs of fœti under the usual term of gestation and up to full time were used, and in addition, five sets of limbs of children up to twenty-seven months of age. For the largest contribution to this collection I must express my sincere thanks to the different officials of the Royal Maternity Hospital, without whose assistance in this matter it would have required a long time to collect this amount of material, to my friends engaged in practice who kindly sent me specimens obtained in their work, and also to several

several students of this University.

One important matter, to which the greatest care was given, was the identification of the age of the specimen. Whenever possible, I obtained an account of the menstrual history of the mother, and by calculating from the date of the last menstruation in the usual manner obtained valuable information as to the age. This occasionally was not available from various reasons, such as pregnancy occurring during lactation. In such cases I was guided by the information from the donor, checked by examination and measurement of the specimen.

In regard to the fœti of nine months in the length of whose limbs considerable variation arose, all so marked were well-developed and large children. In most cases the cause of death was known to me, and I have avoided including specimens which were obviously diseased, and especially those which showed signs of syphilitic infection, as I found that in these the ephiphysial junction showed the syphilitic change, and inclusion of such would have led to doubtful accuracy. Most of the specimens were of fœti which had been expelled prematurely from some maternal

maternal cause, and the full time ones had for the most part died during delivery. One specimen at three months was obtained within the uterus, the mother having died suddenly from pneumonia after only two to three days illness. I have to express my thanks to H.J.Stiles,F.R.C.S. for two of the infantile specimens.

PREPARATION.

The larger specimens were subjected to a uniform treatment. The whole subject was preserved and fixed by injecting into the blood-vessels a solution of formalin of the strength of 4-8 per cent, and using a considerable amount,- several pints for each specimen. The injection was carried out by gravitation, using only a small amount of pressure, 12 to 18 ins. and the subject lay on its back with the limbs in an extended position.
After being left for three to four days the soft tissues were dissected off, the extremities removed by disarticulating the shoulder or hip, and finally the bones disarticulated from one another and the outer layers of periosteum carefully stripped off. Great care is necessary in doing this in the

the neighbourhood of the epiphysial junctions, from the danger of detaching the epiphysis from the diaphysis. The cartilages were preserved in their natural shape and size by keeping the preparations in fluid, using glycerine and water or weak spirit. The natural configuration and dimensions were thus retained- a most important point and one which Humphry notes as being of some difficulty.

Specimens too small for injection, were hardened by immersion in a stronger solution of formalin, or, in one or two cases, in spirit, and treated similarly.

All the specimens and the negatives of the photographs accompanying this Thesis were prepared entirely by myself, and the work was carried out in the Anatomical Laboratory of the University.

I have to express my great indebtedness and thanks to Sir William Turner, both for suggestions as to my work and for his assistance in obtaining references to the work of other observers on this subject.

My work would not have been undertaken but for the information obtained from him in his Lectures on Anthropology, and I have made free use of his notes on that subject, and of his reports on the Challenger

Challenger material.

I have not been able to compare my own specimens with any complete set or with any good illustrations. The illustrations of fœtal bones in most text-books are too diagrammatic and in some cases obviously too inaccurate to be of any use, and I determined to make use of photographs whenever possible to illustrate the different features, to avoid the personal equation present in many drawings.

Only one of these photographs has been subjected to any "retouching," and that one has not been modified in any of the essential characters which it is intended to demonstrate. On inspecting them one or two features are obvious at once as characteristic of the fœtal bone.

The most important and one of the least explicable, is the large size of the cartilaginous epiphysial extremities of some of the bones, especially of the humerus and the femur. In the other bones this character is not so marked, and in the photographs of the radius and ulna especially it will be noticed that the extremities are not much out of proportion to the length and diameter of the shafts. The size

size of these masses of cartilage cannot be explained by the hypothesis that they represent several morphological units which afterwards become differentiated by the appearance of different centres of ossification,- as in the case of the upper ends of the femur and humerus, since in the case of one of the most prominently large,-the lower end of the femur, only one unit is represented and only one centre of ossification appears. Nor is there any mechanical or physical reason which can be adduced to explain their occurrence.

The cartilage which is the primitive model of the shaft is not laid down in any unnecessary thickness, as would be the case were the consistence and strength of the cartilage less than that of bone, and therefore a greater amount necessary to give the same strength to the parts, and the shafts are exposed to more strain than are the extremities.

A third hypothesis,- that the growth of the cartilage is slower than that of the bone of the shaft- is negatived by a reference to the radius and ulna, in which the relative increase in size is the same in cartilage as in bone.

A second feature, resulting largely from the first, is that there is a large mass of cancellous tissue at the epiphysial extremities of these diaphyses. The shaft at that point is expanded to receive the large epiphysis, and the interior is filled with vascular cancellous tissue, and therefore these regions are specially subject to the invasion of infective and pathogenic organisms.

This may explain the frequent occurrence in children of tuberculosis and other disease in these parts of the skeleton.

I have not gone into the consideration of the production of deformities such as club-foot, knock-knee, etc., although I am inclined to think that much information could be obtained on the ætiology of these conditions from a study of the developing bones.

I have confined myself to giving an account from the stand point of Comparative Anatomy and Anthropology rather than that of Pathology and Surgery.

With this preliminary note I will pass to the consideration of each of the bones in detail.

There is one matter in regard to which I wish to prefix a word of explanation. After my information

information had been collected, and in particular after making my own observations on the retroversion of the head of the tibia, a paper was published by Professor Retzius of Stockholm, containing a descript -ion and figures of this character in fœtal and in infantile bones.

I have made use of his observations and given a brief resumé of some of them in the latter part of this Thesis, but my own observations have not been in any way modified by his results, and I am glad to add the name of so distinguished an Anatomist in support of the correctness of my statements on that subject. The priority of publication is his, but my own results have been independently obtained, and, some at least except for his work, are new to Science.

UPPER EXTREMITY.

1. Humerus.

The measurement of the Humerus is that of its greatest length, from the summit of the head to the most distant point of the inferior articular surface. The smallest specimen examined in which it was found possible to measure accurately the length of the bones of the upper limb was a fœtus of about six weeks, whose total length was 35 mills. from the vertex to the coccyx. In it the humerus measured 7 mills. The next specimens were approximately eight and nine weeks old. In the former, ossification of the shaft was visible and the entire osseous and cartilaginous structure had a length of 15.5 mills.: in the second ossification had just commenced and the length was 12.5 mills. Two specimens aged eight and ten weeks had a length of 15.5 and 15.7 mills.
At the third month the bone had reached a length of 23 mills. in two specimens examined. The rate of increase in length in the early stages of development is therefore 5-8 mills. between the sixth and eighth to ninth weeks, and 8-10 mills. as an average increase from the ninth to the twelfth week.

week.

The humeri next in size measured 36 and 36.5 mills. and, as the specimens were about three and a half months in age, we find an increase of 13.5 mills. taking place between the beginning and the middle of the third month.

A slightly larger fœtus had humeri 39-40 mills in length, and this may be considered to be the length attained very shortly after by the rapidly growing bone. In the interval then between the sixth and the fourteenth to sixteenth weeks, the humerus has increased to five times the length it had at the commencement of that period, and this period therefore is one of extreme activity in growth.

The rate of growth is not maintained subsequently. Macalister states that at five months the length of the humerus is 45 mills. but this is rather an under-estimation of the length, as my specimens of this age have a length of 51 and 52 mills. respectively in two specimens rather under that age, and 49 and 50 in two others at the beginning of the fifth month, and it is only in one male child, a twin and therefore presumably smaller than normal, that the bone has a a length of 41 mills.

After the fifth month, the rate of growth is about 8-10 mills. per month, and at the seventh month the length was found to be 65.2 mills.

After the seventh month, some indication is noticeable of a difference in length according to sex. Among the male specimens examined, one, a large and well-developed child of nine months, had humeri of only 72 mills. in length, and the longest male bones did not exceed 84-85 mills. while a female child between the eighth and ninth months had a humerus of 88 mills. in length, and one nine months specimen had a humerus of 90 mills. There seemed to be a tendency for the female fœti to have longer humeri than males of the same age.

These dimensions throw some doubt on the figure given by Macalister as the usual length of the humerus at birth. He states the length then to be 60 mills, but none of the specimens I have examined are so short as this, and most of them exceed it by 20-30 mills.

Humphry, on the other hand, states the length to be 3.5 ins. or 89 mills. which is rather longer than is is usually the case.

After birth the rate of increase is less rapid. In a female child of three months, the lengths of the right and left humeri were 97 and 98 mills. respectively, and at one year 111 mills. At two years and three months the length was 133 mills. The increase therefore is only about 10 mills. in the first three months, 24 mills. in the first year and 50 mills. in the first twenty-seven months. Taking the length of the bone to be under 12 mills. at the second month, this length is doubled at the third, doubled again at the fifth, and nearly doubled again at the ninth month of development. Expressed otherwise, the rate of increase is in harmonic progression from the second to the end of the ninth month.

RATIO OF HUMERUS TO RADIUS AND TO FEMUR.

In 1872 Hamy published a Table showing the radiohumeral indices found at different ages. The number of specimens examined by him is rather small, and, except in one case, he does not state the length of the individual bones, nor the sex of the

the subject from which they were obtained.
He measured one specimen two and a half months old, in which the humerus was 9 and the radius 8 mills. in length, and four between the third and fourth months, and found that the indices at these ages were 88.88 and 84.09 (as a mean) respectively. He also states that the index diminishes gradually till the time of birth, when it is 77.37.

My results do not entirely support his conclusions. The specimens at nine and ten weeks had radii of respectively 12 and 12.5 mills. in length, and from these figures and length of corresponding humeri the indices are 77 and 79 respectively.
In dealing with smaller specimens, the figures are so small that indices are not reliable for giving a true representation of the relative lengths, as the smallest inaccuracy in measurement is multiplied tenfold by the index, and one can measure to a sufficiently minute degree to avoid fractional errors.
I have, therefore, omitted that specimen from the present consideration.
Taking the next specimen, at three months, with a humerus of 25 and radius of 17 mills. the index is

is now 73, and, at the fourth month it increases to 74 and 78 in two specimens, at the fifth month it is 75-78, at the sixth and seventh 72-73, then increases a little, and, at the time of birth it may vary from 73 to 79. After birth, the index definitely sinks, and at the end of the first year is 73, and twenty-seven months after birth is as low as 70.

It will be noticed that in no reliable instance did the index rise to 80, and that the nearest approach to this figure was found at the ninth month, when it was 79- a figure found also by Hamy in one instance at that age. As I have examined a larger number of specimens than that observer (29 as against 22), I do not think that we can accurately say that there is a very regular diminution in the size of the radius compared with that of the humerus during intra-uterine life.

I have endeavoured to show the relative lengths of the two bones at different ages in a graphic manner by means of a plotted curve, the vertical height indicating the length, and the horizontal length the age of the specimen. It will be noticed that the rate of increase is fairly constant, and that the

the line of the humerus gradually diverges upwards from that of the radius as age increases.

One seems to be entitled, from these two methods of comparison, in drawing the conclusion that the length of the radius is greater in proportion to that of the humerus during fœtal life than after development is completed, and that it is within the first two or three years after birth that the humerus elongates so as to produce the ratio found among adults of the same race. The condition found in the embryo is in this feature, rather like the condition found in the Negroes and Australians, in whom the Radio-humeral index is 79.4 and 76.5 in adult life, and shows a deviation to the condition found in the anthropoids, among whom the index rises to 80 in the Gorilla and to 97.8 in the Orang. It is unlike the condition found in the Esquimaux and Lapps, in whom the index is usually low and is stated to be 71.8 and 71 respectively.

(2). Femoro-humeral Index.

This index is obtained by taking the length of the Femur as equal to 100 and comparing with it the length

length of the humerus.

Among the younger specimens, it is found that the length of the proximal segments of the skeleton of the upper and lower limbs is 12 and 13 mills. giving an index of 92 at the second month. At commencement of third month the lengths are 23 and 25, and the index under 90. In the course of this month the index is 89 on an average, and at four months 88.5, becoming still lower, in the fifth month when it is 87.8. The index becomes steadily smaller as develop-ment proceeds, and at the seventh and eighth months is 85.2 and 82.7, and at the time of birth it is 82-84 in different specimens.

The gradation is more regular and constant than was the case of the humero-radial index, and it indicates that at an early age the length of the femur is small in comparison with that of the humerus, but that the inequality between the length of the bones becomes more distinct as development proceeds, the rate of growth of the humerus being steadily less than that of the femur.

This rate of growth is maintained in the two bones after birth, and at three months the index is 80.1

80.1. At the end of the first year it is 78, and at the age of twenty-seven months it is 76.4. Comparing these indices with those obtained from measurements of adult bones, it is again noticeable that the embryonic condition is different to that found in the adult of the same race, and is more like the condition in the lower races of men and in the higher apes. The index in the adult European is 72.5 and the child has not attained to this even at the end of the second year.

But the relative lengths of the two bones is, in this case, unlike the condition found in the Negroes and Australians and is rather like the condition found in the Esquimaux and Lapps, in whom the index is 77.7 and 75.4 respectively. The index is also high in the anthropoids, being 97 in the Orang, a ratio higher than that found in the embryo at any stage of development.

The human fœtus, then, has a high index of relation both between the humerus and radius and the humerus and femur, and the index in both cases diminishes as development proceeds, and diminishes rapidly in the first two years after birth. In this respect the

the fœtus shows an approximation to the conditions in the higher apes, and especially to the orang, rather than to any of the "lower races" of mankind, since it differs in the one respect from those to whom it shows a resemblance in the other.

SHAPE and CHARACTERS of the HUMERUS.

The shape of the bone shows a remarkable constancy through all the stages of development. Beyond the large size of the two extremities as compared with the length and thickness of the shaft, there was little to distinguish the bone from an adult specimen.

The specimens were all carefully examined with reference to the following points:-

(1) Amount of rotation of the head in relation to the transverse axis of the lower extremity.

(2) Presence of a supra-condylar spine.
(3) Communication between the olecranon and coronoid fossæ.

(4) Curvature of the shaft.
(5) Presence of a sex character in the head.
(6) Presence of muscular ridges.

(1) The direction of the articular surface of the head in relation to the transverse axis of the lower end of the bone shows a considerable amount of variation in the different specimens.

At two months, the rotation backwards amounted to 12^{o} as closely as was possible to measure; at three

three months and at three and a half months the rotation was a good deal more, 22-25 degrees; at five months 20-25 degrees, and in bones of a greater age it measured 15-25 degrees.

The amount of obliquity therefore varies at different ages, and may be fully attained by the third month, while after that period there is as much variation as is found among adult specimens.

The rotation was measured with considerable accuracy by fixing the bone at right angles to a ruled surface with the intercondylar plane parallel to one of the lines, and then by laying a transparent "projector" flat on the head of the bone and looking down from above one was able to measure the angle between the line representing the intercondylar plane and the line representing the direction of the articular surface of the head.

One feature about the upper end of the bone was that in the earliest specimens the articular surface was more distinctly marked off from the region of the tuberosities by a groove, especially on the under surface, and at this region the anatomical neck was well marked. The tuberosities were distinctly

distinctly marked all through and the bicipital groove is evident.

2. In no instance was any indication of a supra condylar ~~trochlear~~ spine discovered, and I am therefore inclined to regard it as a post-natal development.

3. There was an entire absence throughout the series of any communication between the two fossæ at the lower end of the bone situated on the anterior and posterior aspects. The intervening layer of tissue seemed to be of an appreciable thickness in all the specimens and was not even translucent in any of the larger ones. Associated with this there is a marked absence of any deep depression to mark the radial and coronoid fossæ, the anterior surface of the bone being almost quite flat down to the point where it joins the cartilage, though the rapid projection forwards of the cartilage from the point of junction gives the impression of there being a deeper fossa than really exists. The olecranon fossa on the other hand, is well marked and relatively as deep as is the case in the adult. The small size of the anterior fossæ is noteworthy, when the fœtal attitude- flexion of the elbow- is taken into consideration, and when the

the well-developed character of the coronoid process is noticed. It was suggested that the absence might be due to a small size of the head of the radius, since the head of that bone is supposed to be relatively small in the child.

But on taking careful measurements of the diameter of the head and of the transverse diameter of the lower end of that bone, I found that the average diameter of the head was to that of the lower end as 2 is to 3. The lower end is certainly not relatively smaller in the child than in the adult, and on measuring the diameters of adult bones I found the same ratio held in them. The upper end measured in them 14 mills. and the lower 21.

This therefore seems to be a feature of the fœtal bone quite distinct from the adult, and not explicable in this way.

4. The curvature of the shaft is slightly forward in the lower part just as in the adult, and it presented no obvious features for examination and comparison.

5. Sex character in the size of the head.

Dorsey, in a paper entitled "A Sexual Study of the size of the Articular Surfaces of the Long Bones in in Aboriginal American Skeletons" has shown that in his specimens the average diameter of the head of the humerus was 8.6 mills. less in males than in females, and I took measurements of the diameter of the head of both the humerus and the femur in a series of specimens. There was no indication of any sex character in this measurement, the ends of the female bones having as great a diameter and as great a proportion to the length of the shaft as the males.

6. There was a marked absence of ridges for muscular attachment on the shaft.
The deltoid impression was distinguishable by a roughening, but the musculo-spiral groove was not developed to any extent.

BONES of FOREARM.

The measurement of both bones was that of the extreme length, measuring in each case to the tip of the styloid process.

1. Radius.

The length of the radius maintains a fairly constant relationship to that of the humerus as has been shown, though a good deal of variation exists in different specimens.

The lengths successively attained are as follows:-

At the sixth week the radius had a length of five mills. and at the eighth to tenth weeks this length is more than doubled and the length is ten to twelve mills.

M. Hamy gives the length of his single specimen as eight mills. at two and half months, but that figure is smaller than may be found at this stage. The same observer notes that at the beginning of the third month we have an alteration in the rate of growth marking the transition from the stage resembling that of the majority of the mammalia to that of the "Primates," and the increase at the third month is considerable. At the third month the length is is seventeen mills. and at the middle of that month the length has increased to twenty-seven mills. denoting a very great activity in growth.

The increase thereafter is less rapid, and, as in the case of the humerus, the commencement of the third month appears to be an age of great growth in the length of the upper extremity as compared with that of the trunk as there is no corresponding excess of activity in the latter.

On the theory of Recapitulation, this period then appears to mark a very important stage in the history of the embryo, showing as it does a transition from a form where the trunk is long and the extremities short, to one in which the upper extremity is increased in length. In the interval between the third and fourth months I have found the length of the radius to be 27, 29, 29, 31.3, 37 and 39, the latter figure being attained towards the end of the month, and at the beginning of the fifth month the length is 38-39 mills. During this month the growth is less rapid, increasing to 42 mills, and, at the sixth, it has a length of 44 increasing to 50 at the seventh, about 60 at the eighth, and during the ninth it may attain a length

length varying from 55 to 70 mills.
The statement as regards a sex difference in the length of the humerus does not seem to hold in the case of the radius, the males having on the whole, radii of about the smae length as the females. The radio-humeral index is therefore at this age rather higher in males than in females, though a larger number of specimens must be examined before this can be consider -ed to be invariably the case.

After birth the rate of increase is considerably less than in the humerus, in fact, the radius only adds to its length about two-thirds the addition made by that bone, the increase in the length of the humerus being from 84 to 98 in three months, to 111 in the first year, and to 133 in two years and three months- a total increase of 49 mills. while the radius increases from an average length of 66 to 73 in three months, 82 in one year, and 94 in twenty-seven months,- a total increase of 28 mills.
I have taken up the relation between the humerus and radius as being more important than that between the humerus and ulna, as this is done by the majority of

of observers, though Charles White in his observations on the gradation in Man and Animals, compares the relation of humerus to ulna, &found that the ulna was longer in proportion to the humerus in negroes than in whites.

ULNA.

The rate of increase of the ulna corresponds very closely to that of the radius. The chief difference lies in the length of the olecranon process and the growth of this process is fairly constant.

During the early part of the third month there is a correspondingly rapid increase in length from 18.5 mills. at the beginning to 30 and 33 during the course and towards the end of that period.

At the fifth month the length is 38-39, increasing slowly to 42 and 44 mills. at the sixth, and 48 and 50 during the seventh, and then attaining a length of 61-76 mills. at the close of intra-uterine life.

The difference in length of the two bones is 1.5 mills. at three months, 3 mills. at three and a half months, 4 at the fourth, 5 at the fifth, about 6 at six months, 6 or 7 at seven months, 7 at eight months, and 6-10 at full time, according to the lengths of the bones.

bones.

The development of the olecranon process then is very regular and the difference between the lengths of the bones increases by almost exactly a millimètre from the third and a hlaf month onwards.

SHAPE of RADIUS and SIZE of ARTICULAR ENDS.

Like the humerus the shape of the radius is very constant. Even at the earliest age it presented the cup-shaped head, the constricted neck, the curved shaft and the expanded lower end characteristic of the adult bone.

The curvature of the shaft is as well developed, relatively to the length, in the fœtus as in the adult, and the curvature backwards of the shaft at the middle was pronounced. This suggested the presence of considerable muscular development in the muscles attached, and it is of interest to note in connection with this the well-known prehensile powers of the hand of the child. From the conformation of the shaft of the bone one would presuppose that it had given attachment to powerful muscles and especially to powerful

powerful flexors and extensors of the fingers. The transverse diameter towards the lower end of the shaft was greater in proportion to the length than is the case in the adult, being 8 mills. at the upper border of pronator quadratus in a bone 66 mills. in length.

Size of Head. This has been referred to in connec-tion with the absence of a radial fossa at the lower end of the humerus. On measuring the diameter of the head and the transverse diameter of the lower end the former was found to average ten millimètres and the latter fifteen millimètres, or a ratio of two to three, while in adult bones the diameters of the two ends were respectively 20-30 and 30-35 mills. respectively, in the specimens examined, and the individual relationships of the ends were almost exactly as 2-3 in every case. The head of the radius therefore does not seem to be smaller in proportion to the lower end than is the case in the adult. The transverse diameter of the shaft at the upper border of pronator quadratus in the adult is 14 mills. in a bone 204 mills. long, and 19 in a bone from a mus-cular subject 243 mills. in length. In the gorilla

gorilla, the bone was found to have the wide transverse diameter of 36 mills. in a bone 365 mills. long- or equal to one-tenth of the length, while in the embryo the width was one-eighth of the length, and in the muscular adult the ratio was one-twelfth of the length.

Ulna.

The ulna shows very much the same features as the radius- a well developed olecranon, a deep sigmoid fossa for the humerus and a prominent coronoid process. The shaft is broad and the curvature is marked, and the whole bone presents a development similar to that shown by the radius.

METACARPUS and PHALANGES.

The rate of growth in these bones was examined in a series of specimens, and, for purposes of comparison the metacarpal bone and phalanges of the index finger, and the metatarsal bone and phalanges of the second toe were selected as being representative of the condition in the respective sets of bones- the right limb being used in each case. The skeleton of the hand and fingers is laid down early in development and attains a considerable length at an early date. In a specimen at the third month the length of the metacarpal of index was 7.3 mills. and of the phalanges 10.2 mills. the combined length being only .7 mills. less than the length of the radius at that age. At three and a half months the lengths were 8.3 and 11.6 mills. respectively, an increase of only 1 mill. and 1.4 occurring in the two segments. At four and a half and five months the lengths were 11.6 and 12 for the metacarpal and 15.6 and 15 for the phalanges- the phalanges being 4 and 3 mills. longer than the metacarpals. At eight months the lengths were 18.6 and 25, and at nine months 22 and 23, in one case, and 22 and 30 in another, the difference amounting to to 6 and 8 mills. in favour of the phalanges at the time of birth, and the combined lengths being 50 and 52, while the corresponding radii increased to 63 and 67 mills. or a difference of 13 mills. and 15 millimetres of excess in the length of radius.

At three months after birth the lengths were 30 and 33 mills. as against a radius of 73- a difference of 10 mills. The relative growth of the metatarsal and its phalanges is fairly constant, the phalanges being one-third to one-fourth longer than the metatarsal at the third month and holding that relationship at birth, while subsequently the growth of the metacarpal bone is more pronounced.

The metatarsal bone and its phalanges measured 8.2 and 6.5 at the third, and 7 and 7 in another specimen at three and a half months, and at this age the meta-tarsal may be apparently equal to or longer than the skeleton of its digit. At four and a half and five months the lengths were 12 and 12, and 11 and 10 respectively, showing still a very similar relationship and an increase of 3-5 mills. in each segment from the beginning of the third month.

But at the eighth month the metatarsal measured 21.5

21.5 and the phalanges 15.6 showing now that the metatarsal had begun to acquire the relationship in length to the phalanges present in the adult.

At nine months the lengths were 18 and 23.71 for the metatarsal and 25 and 19 for the phalanges in two specimens. Thus while the metacarpal and its phal-anges maintain a constant ratio of length, the meta-carpal being the shorter, in the foot the two segments may be originally of the same length, and only in the later stages does the adult ratio appear.

The other fingers and toes were not examined as regards their length. In configuration the bones in both series presented the adult characters as far as could be made out, and this seemed to be the case also in the thumb and in the great toe.

LOWER LIMB.

1. Femur.

The measurement of the femur was that from the summit of the head to the most prominent point on the condyle, usually the external, but in one or two cases the internal.

The complete measurement of the length of the adult bone, as given by Turner, includes the measurement from the tip of the troc~~hlear~~hanter to the external condyle, but I have not included this in my series of measurements as the small size of the specimens rendered this diameter only slightly less than the other, and as the former measurement is that of the complete length of the bone, it is the most useful for purposes of comparison. I have, however, added a series of measurements, chiefly from full time specimens, giving the diameters of the head, the length of the neck measuring from the head to the outer part of the great trochanter, the maximum transverse diameter of the condyles and the antero-posterior measurement of the condyle.

It was found impossible to measure the length of the segments of the lower limb at six weeks as they were

were not sufficiently developed.
In the eight weeks specimen the femur measured 13 mills. and in the next oldest 21. At the beginning of the third month the length was 25, and in the specimen of three and a half months 39.5. This increase of 14.5 mills. in so short a time at first suggests that the age must be greater than is represented, but I have made special enquiry on this matter and I feel myself obliged to state the age as being only three and a half months. The increase at this time corresponds to the rapid increase which has been shown by other observers to take place in the skeleton of the upper limb about this period, and a similar increase occurs at the same time in the lower extremity. A little later, the length increases to 36.5 mills. and between the fourth and fifth months the length is 46-47 mills. During the fifth month the increase is more gradual, and at five and a half months the length is 49 increasing after this more rapidly to 59 during the sixth month and 62 at the seventh, to 70 at the eighth, and, at birth, it has a length of 87 to 100 mills. and in one specimen it attained to a length of 108 mills.

mills. The increase in the latter months is therefore rapid. Taking the length to be 13 mills. at the eighth week, this length is doubled at the third month, doubled again between the fourth and fifth, and nearly doubled at the ninth, the chief increase occurring in the last month and a half of intra-uterine life. Comparing this rate of growth with that of the humerus on the plotted curve, the femoral line is seen to accompany that of the humerus pretty closely to the third month when it begins to diverge away from it, and continues to do so steadily till birth. After birth the length was found to be 121 at the third month, 142 at the twelfth and 174 at the twenty-seventh, increasing thus 20-25 mills. in the first three months, 20-25 again in the next nine, and 30-35 in the next fifteen.

Shape of Femur.

1. The angle formed by the meeting of the axis of the head and neck with the axis of the shaft was carefully measured.

Considerable discrepancy exists between the statements made by different observers. Thus Rodet (Th. de Paris, 1844) states that the axis of the neck

neck makes with the axis of the shaft an angle of $130°$, and that this angle is on an average $2°$ larger in the infant.

Macalister states that the "angle of the neck" of the femur is at birth $160°$.

Humphry publishes a Table giving the measurements of the angle of the neck with the shaft at different ages, and among his fœtal specimens found a good deal of variation, the angle varying from $128° - 141°$, and having a tendency to be larger in early embryonic life.

None of these observers state how their results were obtained, and therefore one cannot compare their results and mine with great precision.

The method I adopted is as follows:- the line of the axis was represented by a straight edge passing from the centre of the intercondylar depression upwards through the middle of the shaft, and the axis of the neck was represented by a line drawn from the centre of the head just above the attachment of the ligamentum teres along the neck midway between the upper and lower borders in the axis of the neck, and inter-secting the axis of the shaft in the majority of of cases just at the junction of the upper epiphysis with the diaphysis. The results obtained showed that at three months the angle was almost 135°, at three and a half and four months 129° and 126°, and in several specimens at the fifth month it ranged from 131°-134°. At seven months it was 128°, at eight months 127° and at nine months on an average 126°. After birth it was 125° in a female at three months and 120° in another at one year, and 125° in a male at twenty-seven months.

The average angle in the specimens under five months was 130, in those over five months 127.1° and in those after birth 123°.

There seems therefore to be a gradual diminution in the size of the angle of the neck and shaft after the fifth month and again after birth, till the average adult angle of 124° is attained.

But no angle smaller than 120° was found in intra-uterine specimens, while in adults it falls occasionally to 113, and no angle greater than 135° which is within one degree of the maximum attained by adult bones. In regard to sex difference, which is shown in adults by a smaller angle in the female, of the specimens of of five months and over the average angle in the males was 126.5°, and in the females 126.1° - the difference between the two being too small to be of importance. The largest and the smallest angles in the series were found in males.

Comparing these figures with those given by Humphry that observer found the angle to range from 141° to 128, with an average angle of 135° in his specimens under five months and an average of 128° in those over five months, a figure very similar to that obtained in my specimens.

The change in the size of the angle seems to take place within the first year after birth, and if this is the case, is independent of the weight of the body.

The other peculiarities in the shape of the femur will be described with the Tibia.

TIBIA. Rate of Growth.

In the adult the tibia presents greater variation in length than any other bone in the body, not only between adults of different races but even in the length of the bones of different individuals of the same race.

The measurements which have been employed to estimate the length are three:-

1. From the summit of the spine to the tip of the malleolus.

2. From the condylar surface to the malleolus,
3. From the condylar to the astragaloid surface.

I have selected the second measurement for use throughout the series. I have also made use of the third in a number of cases but have appended the results obtained from the second uniformly.

At eight weeks the bone had a length of 9.5 mills. and at the tenth week the length was 16 mills. At twelve weeks the length was 17.5 and 18 mills. in two specimens, an increase of 8-8.5 mills. from the eighth week length. At three and a half months the length was 29.5 mills. and about the beginning of the fourth month 35 mills.

mills.

The increase then in this segment of the appendicular skeleton is similar to what has been shown to occur in the other segments about the same time, and in the tibia amounts to 17 mills. in rather less than four weeks. At the fifth month the length increases to 46-49 mills. and at the sixth and seventh months to 59-63 mills. After a regular increase then in length, the bone, at the time of birth, presents a great deal of variation, measuring 70 mills. in one specimen, 72 in another, 82-85 in the majority, and even attain-ing a length of 90 mills. in one specimen. The variation in length then is from 72-90 mills and it is worthy of note that this is precisely the amount of variation found in the humerus at the same age.

During intra-uterine life the two bones retain a very close relationship but it is an almost invariable rule that at this period the humerus is the larger of the two bones. The difference is most marked about the middle of development, and towards the end the bones tend to become of the same length. The adult European tibia exceeds the humerus in length to a considerable extent in the great majority of cases, but this

this is a character only developed in adult life. In the infant at three months the length of the tibia was 94 mills. an increase of only 10 mills. from what we may take to be an average length at birth 84 mills. at one year the length was 115, making a further increase of 11 mills. in nine months, and at twenty-seven months the length was 133, an increase of about 20 mills. in fifteen months.

The adult relation to the humerus was not attained even at this age, the humerus having the same length of 133 mills. at this age.

The precise differences between the lengths of the two bones in intra-uterine life were, at six weeks $2\frac{1}{2}$ mills. at three months 6 mills.; at four months 4-5 mills. ; at five months 5 mills.; at seven months 2-3 mills. and three months after birth 3 mills.

The relation of the length of the tibia to that of the femur also presents considerable variation, and, on the whole, a marked difference from the ratio existing bet-ween the two bones in adult life. The relationship between them corresponds rather to that found to exist between the humerus and radius at different ages, inasmuch as the general tendency is for the

the index in both cases to be larger than it is among adults, though there is no very regular gradation to be made out from the earlier to the later stages. Taking the length of the femur as 100, we find the tibia to be 73 at the eighth week, 70 at the third month, but at the middle and towards the end of this month the index rises to 75.6 and 79.5 and even to 82.9.

In the radio-humeral index on the other hand, the index became rather smaller about the middle of the third month, but rose again towards the close.

Between the fourth and fifth months the tibio-femoral index remains high, varying from 81-83 in different specimens. At the sixth and seventh months it became 80 and 81, and maintained the same height to the end of intra-uterine life, rising even in one specimen to 87, though the majority of the specimens had an index of 81.

The alteration after birth is very marked, and at the third month the index had fallen to 77; at the end of one year was 80, and again at twenty-seven months had fallen to 76.

The relationship to one another of the lengths of the

the two upper segments of the lower extremity varies then considerably during development, though the averages at different ages are not very different. This is a very interesting fact when taken in consideration with the ratio found among different races of mankind and among the apes. The tibio-femoral is the only limb index which is not greater in the apes than in any human species. The European index too, presents a condition midway between the two extremes of a low index in the Lapps and a high index among the Andamans and is only slightly lower than the index found in the gorilla and orang.

The evidence given by this observation in the fœtus would rather go to sustain an homology drawn from the other limb indices between the condition found in the fœtus and that found in the anthropoids.

The inclusion of the malleolus in my measurement of the tibia does not make any serious difference between the results I have obtained and those of other observers.

In the only two descriptions of a fœtal gorilla which I have been able to find, one by Deniker, whose specimen was 196 mills. long, and the other by by Duckworth, the leg - thigh indices work out at 67.3 in the former, and 76.4 in the latter, a condition very different to the femoro-humeral indices of the adult, and indicating that during the course of development it may approximate in this respect to the condition found in the human being.

The Fibula plays no important part in the skeleton of the lower limb in the adult, and it seems to be merely an accessory structure for muscular attachment in the fœtus as in the adult. Even in the earliest specimens, I found no confirmation of the statement that the upper end of the fibula articulates with the lower end of the femur, but, on the other hand, it seemed to have a relationship to the upper end of the tibia exactly similar to that of the adult.

Its rate of growth corresponded very closely with that of the tibia. At the third month it measured 15.7 mills., nearly two mills. less than that bone; between the third and fourth months it measured to 28 and 30 mills.- being about four mills. less than the tibia; and at the fifth month 41-43 mills. At seven months the length was 58-60 mills. being then 3-4 mills.

mills. shorter than the tibia; and at birth the length varied, with that of the tibia, from 69 to 82 mills. and it was, as a rule, about six mills. shorter than that bone.

The relative length of the malleoli was carefully examined before the bones were separated from one another. In dealing with this Gegenbaur has stated that the tibial malleolus is the larger of the two until the seventh month of intra-uterine life, and that, after this age the two malleoli are of about the same length, and that the adult proportions are not attained until the second year of life. This statement has been extensively quoted and appears in many text-books. On the other hand, Minot in his recent work on Human Embryology figures a coronal section of an ankle-joint at the sixth month, in which the fibular malleolus is shown to exceed in length the tibial to a very evident extent.

My own observations show that even at the third month of intra-uterine life the fibular malleolus is the longer, and in every case examined of an older age this was found to be the case.

At birth, the fibular malleolus is, as a rule, three

three or four millimetres longer than the tibial and they therefore present the adult relationship even at this early stage.

The superior articular surface is always in contact with an oblique surface on the external tuberosity of the tibia, and the plane of this articulation was not in any single case found to be horizontal as is stated by some authorities to be the case.

Having now determined the rates of growth of the different long bones of the limbs and the ratio which the different segments bear to one another, expressed by the radio-humeral, the humero-femoral and the tibio-femoral indices, it still remains to express definitely the ratios which the upper and lower limb present to one another at different ages, and, as in anthropological work, to calculate the intermembral index or the ratio which the combined length of the humerus and radius bears to that of the femur and tibia.

The statement made on this subject is usually this, that the superior extremity is larger in comparison with the inferior in the fœtus than in the adult, and

and the general fact is made use of by artists in their representations of children.

M. Sue's conclusions on this point are drawn from the entire length of the extremities, in which presumably he includes the length of the hand and the distance from the internal malleolus to the sole of the foot. From these data he finds that the upper limb is longer than the lower one up to one year after birth and that only a slight difference can be made out even three years after birth.

From Humphry's measurements, some of which it has been shown, are rather in excess of what is usually met with, taking the humerus at birth as 90 mills., the radius 64, the femur as 107 and the tibia 90, the respective lengths of the two segments would be 154 and 197, giving an index of 78.1, while at the seventh month the same segments measure 140 in the upper limb and 153 in the lower, giving an index of 91.5.

From his figures there is obviously a considerable difference in the index at different ages and it is important to know what the index may be expected to be at any age and at what period the greatest changes occur. Taking then as measurements the maximum

maximum length of the humerus and radius, and of the femur and tibia as described, in the earliest specimen the index works out at 97, which indicates that at this age the two limbs are practically of the same length. At three months the index is still almost as high, namely 96, and therefore though the different segments are at this age nearly twice as long as they were at the former they have not altered to any appreciable extent in their relative lengths.

The ensuing period, from the beginning to the middle of the third month, has been shown to be a period of great incremental activity marking an alteration in the configuration of the embryo, and it is interesting to find that this period also marks an alteration in the relative length of the limbs. The index falls from 96 to 92 at the middle of the month, to 86-88 a little later and between the fourth and fifth months to 85 and 84.

In one specimen at the sixth month the index was as low as 79.5, but I have not obtained the high index of Humphry's figures at the seventh month although my results agree with his in showing that the ratio at birth is nearly 80, indicating a relatively long upper

upper limb compared with what is found in the adult. Three months after birth the index was found to be 79, after one year 72.5, and at the end of twenty-seven months 73.9. The first year of infantile life then, as has been previously shown in comparing the rate of growth of the different segments at this period, is a time during which the lower limb elongates out of proportion to the upper. The two segments undergo an alteration in their length almost as great as that occurring between the second and ninth months of development.

The relationship which the fœtus presents to the lower races and to the anthropoid apes is now quite distinctive as may have been gathered from previous comparisons.

The different races of mankind cannot be classified with accuracy into those which in their intermembral index resemble the apes and those which do not, since the index in the apes is high, being 104.6 in the orang, 118 in the gorilla and as great as 141 in the chimpanzee- these figures indicating that these animals have lower extremities which are absolutely shorter than the superior- while throughout the

the different races of mankind we find the index very much smaller, 69.5 in the European, and varying only to a comparatively small extent throughout the series from 67.3 in the Bush people, to 73.8 in the Esquimaux. Again then, we find that the fœtus in the course of its development presents a greater resemblance to the ape form than does any human species, and this important fact is made out that while, as Turner has pointed out, no single race approximates in all its measurements and ratios to the condition found in the ape, those which resemble it in one respect differing from it in another, in the human fœtus we find a condition approximating to the pithecoid form not only in the relative lengths of the segments of the upper and lower limbs but also in the ratio which the shaft of the upper limb presents to that of the lower.

Having now considered the rate of growth of these different limb bones I turn to the investigation of the special characters which are found present in the fœtus. The most striking of these is the shape and configuration of the head of the tibia in which is is seen a condition which has long been known to anatomists to be present in the tibiæ of lower races and of certain prehistoric human remains. As the significance of this condition is not yet very clearly understood, the following historical resumé of the descriptions and explanations that have been given is not out of place.

In 1863 Hueter in a communication entitled "Anatomical Studies of the joints of the new-born Child and the Adult" described the head of the fœtal tibia as being retroverted and the condylar articular surface as being oblique, downwards and backwards at the time of birth. He did not complete the investigation of these features by examining earlier fœtal material but only described it as being present at birth and disappearing as age advanced and as the child adopted the erect attitude.

The explanation he gave was a mechanical one, namely, that the peculiarities in the head were due to the greater development of the flexor over the extensor muscles of the knee, and to the flexed and cramped position within the uterus.

After this, in 1880, M. Collignon was the first to to describe a condition of "retroversion" of the tibial head found by him in the bones of prehistoric quaternary skeletons found in Bollwiller, and he drew the conclusion from the shape that the gait of the persons who possessed tibiæ of this conformation must have been less erect than the gait of the modern civilised man and similar to that of the gorilla in whom the head of the tibia is retroverted. The same condition was described by Fraipont and Lohest as being present in the bones of the skeletons, also prehistoric, found at Spy, and the same conclusions as to the gait were drawn from this configuration. The same condition was again described by Testut in another tibia found in the remains from the Dordogne at Reymonden. In 1886, Professor Sir William Turner [redacted] pointed out modifications in the skeleton which might be brought about by habitual attitudes and occupations, and attributed modifications in the shape of the pelvis and lumbar region of the spine to the squatting attitude adopted by certain races, and in 1889 Professor Arthur Thomson of Oxford worked out in detail modifications in the head of the tibia and in the lower end of the tibia and the neck of of astragalus found among races whose habits of squatting are known. In his paper he pointed out that the form of the tibia undergoes frequent changes and that the change in form is due, in most instances at least, to the influence of posture. Examining first the curvature of the external condyle he found varying degrees of convexity in the different races of man, and found that in the higher races the convexity is but slight. From the material examined he was led to conclude that the convexity is less when a backward curve of the head is present, but makes no special mention of an oblique direction of the upper surface. He also described the occasional presence of occasional facets on the anterior margin of the inferior articular surface of the tibia and on the neck of the astragalus, which are in contact with each other in extreme flexion of the foot or the leg. These facets are of rare occurrence in the higher races and are found almost invariably in savage races, and this condition he also attributed to the squatting attitude.

The facets were also found to be well marked in the gorilla and the orang but less frequently in the

the chimpanzee. At that time there was no evidence to lead to the supposition that these peculiarities are transmitted characters, but the bulk of the evidence went to prove that they may be acquired.

In the year 1890, Manouvrier, and a few years after, Professor Havelock Charles published further information on this point. The former pointed out that "retroversion" of the head of the tibia is found in Neolithic man, in savage races and also in modern Parisians to an extent as great as that in the Spy and Bollwiller remains, and that these people were all capable of assuming a vertical attitude.

The latter examined the bones of the modern Punjabi and found in them modifications similar to those described by Thompson, and also associated them with the squatting attitude. He also finds a slight amount of obliquity in the tibial head. He further found that the neck of the astragalus in the full-time Punjabi fœtus and infant displayed the same condition, and put this forward as evidence in favour of the inheritance of characters acquired by the ancestors as he states that these conditions are not present in the European infant or fœtus.

fœtus.

In 1894 Professor Macalister demonstrated the presence of the articular areas on the neck of the astragalus at a meeting of the Anthropological Society, and showed that they were present in the British infant. In 1897 Sir William Turner in his Presidential Address to the Anthropological section of the British Association described retroversion of the head of the tibia without obliquity of the condylar surface, in the tibiæ of people of the Bronze Age, and referred to the investigators whom I have quoted and drew attention to the fact that in order that retroversion of the head of the tibia should be associated with inability to extend the knee it is obvious that the articular surface should have a marked slope downwards and backwards as in the case of the anthropoid apes, when the shaft of the tibia is held vertical.

Since making my own observations on the condition found in the fœtus at different ages Sir William Turner directed my attention to a very recent paper by Gustav Retzius on this subject, (see reference) in which the condition of the head of the tibia is figured and described in the newly-born child- only published

published within the last few weeks.

Retzius criticises Hueter's "mechanical theory" which he cannot accept for two reasons. In the first place he finds as I have done, that the head of the tibia in the fœtus is distinguished by three features,

(1) Retroversion of the head, or a carrying of the upper epiphysis backwards from the axis of the shaft.

(2) Obliquity of the condyles, the slope being downwards and backwards.

(3) Convexity of the external condylar surface and con~~vex~~cavity of the internal.

These three characters are present in the fœtus from the third month on to full time, and he cannot there-fore accept the explanation that the weight of the body presses on the knee, since, at that time, the body floats in the *liquor amnii*, nor can he understand that the muscular "tone" produces effects on the head of the tibia particularly, especially the internal condyle, and not also on the menisci and the condyles of the femur. He also figures the head of the tibia and fibula in children of two months, four months, seven months and thirty-seven months. At two months

months the fœtal retroversion is well seen and the upper articular surface slopes well back and the convexity of the external condylar surface is distinct. At four months the condition is less marked, and at seven months it has almost disappeared, and in his specimen there is a close approximation to the adult form.

He therefore concludes that the correction occurs in the first six months, before the child can walk and so bring the weight of its body into play on the head of the tibia, and that therefore, the mechanical theory is open to objection. Showing in another way when and why the fœtal condition changes to that of the adult, he measured the angle which the sloping articular surface makes with the axis of the tibia, and finds it to be 50°-65° between four and eight months, 65° at nine months, but after birth at two months the angle is 70°, at four months 76°, at five to five and a half months 75-80°, at eight months 85°, at ten to twelve months 85-88° and at twenty-one to thirty-seven months 85-88°.

He rather ascribes the fœtal form to the innate tendency which different parts of the body have to assume

assume a certain form.

Before going into this question of ætiology it will be well to describe in some detail the condition in the fœtus and child of those parts of the skeleton of the lower limb which have more or less a distinct character in man.

These are especially

1. The head, shaft and lower articular surface of the femur.
2. Tibia.
3. Astragalus.

and in doing this I must acknowledge my indebtedness to the excellent resumé of the characters which distinguish the skeleton of the shaft of the lower limb from that of the ape, given by Sir William Turner in his Presidential Address to the Anthropological Section of the British Association in 1897, and to the careful examination by Dr Hepburn of the femur of different races published in the Journal of Anatomy.

1. FEMUR.

In the upper end of this bone Turner has described a prolongation of the articular surface of the head on to the anterior aspect of the neck for articulation with the posterior aspect of the ilio-femoral band in extension of the joint. This facet is usually found, though in a varying degree of distinctness, in the adult European bone, but is not present in the femur of the apes in whom the erect attitude is not adopted. In the apes, the head is on the other hand rather mushroom-shaped and clearly marked off from the neck all round by a border which overhangs the neck, so that the diameter of the head at its junction with the neck everywhere exceeds that of the neck at the same region. This is a distinct pithecoid character, and it was with some astonishment that I found on examination of this region in the full time femora that to a greater or less extent a similar mushroom-shaped character was evident in the head. On carefully removing the periosteum over the neck a distinct elevation running round the whole periphery is present at the junction of the head and neck. In the whole series, from the earliest age, the same

same appearance could be made out and the articular area on the neck is only developed some time after birth in response to the demands of the erect attitude.

2. Characters of the Shaft.

Hepburn in a communication on the platymeric, pilastric and popliteal indices of Femora" has given a large number of measurements and describes interest-ing modifications of the bone in different races. Many of these variations in the shaft are ascribed to muscular attachment and the bones of the embryo are too small to permit of accurate measurements being taken to a sufficiently minute degree to allow small variations in the different diameters. I have however, appended a projection of a cut surface displayed on making a transverse section through the popliteal region of a femur of twenty-seven months, just above the highest point of the anterior articular surface. The shape of this part of the bone is very different to that found in the adult, being much wider from side to side and flatter from before backwards, and resembles his section from the same region of the femur of an adult gorilla. His paper also contains many

many interesting measurements of the ends, and I have appended a series of measurements of different diameters of the bone.

The ratio of the diameter of the head to that of the bicondyloid diameter in the fœtus is as 1 is to 1.9 or 1 to 1.7- corresponding very closely to what is found in almost every adult femur, but the higher figure is said by Hepburn to be the ratio found in the gorilla and chimpanzee.

The head and the lower end- especially the latter- are larger in proportion to the length of the shaft than is the case in the adult, the shaft measuring 9.6 times the diameter of the head in the adult while in the fœtus it is 6 to 8 times the diameter only

The large size of these structures may be variously interpreted as being either morphological or purely physical, but I do not feel myself justified in draw-ing a conclusion one way or the other.

Passing now to the configuration of the lower end of the bone the human adult femur is distinguished by a deep trochlear groove, by an external condyle,

condyle appreciably larger than the internal, by an intercondylar fossa narrow in front but widening behind. The thigh can be fully extended on the leg, but the articular area is not prolonged on to the upper surface of the internal condyle.

The accompanying illustrations show the condition in the fœtus, which is as follows.

The trochlear is a wide, shallow sulcus with margins less prominent than in the adult, and the surface hardly rises so high on the anterior aspect on the outer side as in the adult.

In front of the notch the groove is shallow but is seen to become relatively deeper as age advances.

There is no line of demarcation on the articular cartilages between the trochlear and the condylar surfaces. The articular surface of the internal condyle is prolonged backwards on to the upper aspect to a greater extent than in the adult, and there is even a smooth area just above the condyle on the posterior aspect of the popliteal surface of the bone, below the area for attachment of the inner head of the gastrocnemius.

The intercondyloid notch is a wide horse-shoe shaped

shaped interval,wide in front and narrowing slightly at the back.

TIBIA.

In the upper end of the tibia from the third month onwards three characters can be made out, namely, (1) a carrying backwards of the axis of the upperepiphysis, so that it diverges backwards at the upper end from the axis of the shaft of the bone.

(2) An oblique direction of the articular surfaces, especially of the inner, the surface forming an angle of 30-40° with the axis of the shaft.

(3) A convexity of the external condylar surface and a concavity of the internal, the external articular surface being continued on to the posterior aspect.

Lastly, the knee joint cannot be fully extended so as to bring the axis of the femur into line with that of the tibia.

TIBIA.

In the upper end of the tibia from the third month onwards three characters can be made out, namely,

(1) a carrying backwards of the axis of the upper epiphysis so that it diverges back-wards at the upper end from the axis of the shaft of the bone.

(2) An oblique direction of the articular surfaces, especially of the inner, the surface forming an angle of 30-40^{o} with the axis of the shaft.

(3) A convexity of the external condylar surface and a concavity of the internal, the external articular surface being continued on to the posterior aspect.

Lastly, the knee joint cannot be fully extended so as to bring the axis of the femur into line with that of the tibia.

These three characters are a reproduction of what has been described in the tibiæ of the apes and of some prehistoric skeletons, and two of them are characters

characters present in the tibiæ of some modern peoples. In the specimen at the third month the tibial head is retroverted and the obliquity well marked. This obliquity causes an apparent projection forwards of the anterior tubercle.

In order to measure the amount of retroversion and the amount of obliquity two measurements should be taken, the first to determine the angle included between a line drawn from the centre of the tibial spine to the centre of the shaft at the junction of the epiphysis, and the continuation of a line representing the axis of the shaft. The second, by measuring the angle formed by a line representing the upper surface of the internal tuberosity and the line of the shaft continued upwards.

The first angle is smaller than the second, and there -fore the obliquity is not due merely to the tilting backwards of the epiphysis as a whole but is an additional feature.

The same condition is found at five months, at seven months and at full time, being more and more obvious as the size of the parts increase. The amount of convexity of the external surface varies slightly

slightly in different specimens, but the articular surface is usually prolonged backwards on to the posterior aspect of the head, probably, as Thompson has suggested in the case of adults, for articulation with the external intra-articular cartilage and the tendon of the popliteus muscle in the flexed position. In all the specimens the internal surface is concave and depressed below the level of the external.

The fœtal conditions disappear rapidly after birth. In the specimen from a child of three months the condition was modified to a considerable extent, the retrogression and the obliquity disappearing to an equal extent, but the external surface retained its strongly convex form and was prolonged backwards.

At one year the fœtal condition had practically disappeared and little difference can be be made out in the configuration of this specimen and that of the twenty-seven months old one, and the shape of the latter, in turn is similar to that met with in an adult.

Perhaps the most curious features about this condition are its early appearance during intra-uterine life and its rapid disappearance within the first year of of infantile life. In considering the ætiology of this condition it must be borne in mind that the fœtal intra-uterine attitude is one of flexion from the beginning.

The entire embryo presents a curved outline and the extremities are flexed upon the trunk. During the later stages of intra-uterine existence the fœtus is to a certain degree cramped, though movements of the limbs can be carried out. But in the early stage it floats free within the liquor amnii and there is no physical reason why the extremities should be develop -ed in a flexed attitude, beyond the innate tendency of the parts to assume a certain type form.

In the case of the upper limb the structure of the joints does not produce any modifying influence on the movements or vice versa, but in the case of the adult it is known that in the lower limb the adoption of a certain attitude has a tendency - from the new physical strain on the parts involved by the supporting of the weight of the body in that attitude- to cause a certain modification of structure, one of which at least is known to be a retrogression of the head and a convexity of the external condylar surface, without

without any impairment of the movement of the joint in other directions. The embryo however, is not subject to the same conditions. At no time has it to support the weight of the body, and therefore no strain is involved by the attitude of flexion, since even an adult with a straight tibial head and flat or horizontal condyles can flex his knee to an extent limited only by the contact of the leg with the thigh. In the adult it is only when the weight of the body has to be supported by the flexed extremities that a new strain on the parts is introduced, leading to certain modifications in structure.
It is, furthermore, worthy of note that in these cases in which an "attitude-modification" is described, retroversion of the head of the tibia is associated with a flat external condyle, e.g. in the negro, in whom Thompson finds that a flat condylar surface is placed obliquely and associated with a backward curve of the upper extremity of the shaft, and in whom the curvature is explained as being compensatory to and explaining the unusual flatness of the condyloid surface. On the other hand, the convex external condyle is associated with "retrogression." It is

is unfortunate that Thompson, in his valuable paper, makes no enquiry into the amount of retrogression of the head or the degree of obliquity of the articular surfaces. It is evident that more information in these two matters is required before any positive statement can be made in comparing the adult with the fœtal configuration. From Charles' specimens the amount of obliquity, as previously remarked, is slight, and the convexity of the external condyle is more marked. From the consideration of these two facts one would presuppose that the individual would be capable of standing erect, "like a soldier." In considering the significance of these conditions we must draw a distinction between these tibiæ which present a simple retroversion of the head and those which present a retroversion together with an obliquity of the superior articular facets. The former condition, as has been shown by Turner, is not uncommon in tibiæ of the Bronze Age and is that met with in the specimens of Manouvrier and Charles. This condition may be called "retrogression." The latter author describes an obliquity of the internal condylar surface, but I have examined his specimens presented to the Anatomical Museum,

specimens and noted that the obliquity is only slight, not comparable with that met with in the fœtal bone, and such as is frequently met with in European tibiæ. This condition of "retrogression" of the tibial head, with a condylar surface which is horizontal when the axis of the bone is vertical, is not incompatible with the adoption of the erect attitude.

But the other condition, for which the name retroversion is very suitable, implying an obliquity of the condylar surface as well as a retrogression of the head, is on a different physiological footing.

To determine whether complete extension of the knee joint was possible in a limb of this configuration, I made some investigations into the movements of the joints of the lower limb in some newly-born children. The results were as follows. In two children aged one day the hip-joint could not be fully extended by the child nor even by the application of force. Laying the child on its back on a flat surface and bringing the knee down to the level of that surface the pelvis tilted forward and the spine became arched forward in the lumbar region. This happened even when the child was asleep. At the same time the knee

knee could not be fully straightened. The maximum amount of extension attainable at that joint only brought the axis of the femur into a line which, continued downwards, met the toes at their extremity or at their root. The ankle joint was capable of being greatly flexed but only extended to a limited degree. The flexion allowable was such that the sole of the foot was nearly parallel to the axis of the leg, while in the extreme extended position the angle formed by the shaft of the leg and the foot was about 100-115° degrees.

In a child two days old of large dimensions the same condition was made out, and in a female child born at eight months and with thin limbs the condition was very noticeable. The movements of the upper limb on the other hand seemed to be in no way restricted. It is therefore obvious that the new-born child is physically incapable of adopting the erect attitude, not only on account of the weakness of the nervous and muscular systems but also from the configuration of the skeleton of the lower limb. But changes occur in the skeleton before it begins to assume the erect attitude, so that, at the end of the first year of of infantile life, that attitude is possible as far as the knee joint is concerned.

The ankle joint also becomes modified about the same time. By the second year the obliquity of the neck of the astragalus has disappeared though the additional fœtal articular areas remain, as hereafter described.

In the lower end of the tibia there is usually a well marked articular facet on the anterior aspect articulating with the neck of the astragalus in extreme flexion of the ankle joint. This surface is widest at the inner part but extends along a considerable part of the whole anterior margin. It corresponds to the areas described by Charles as occurring both in the adult and fœtal Punjabi and articulates with an area on the upper surface of the astragalus exactly similar to that in his specimens. This feature, unlike those at the upper end of the tibia, persists until the commencement of the second year of infantile life.

The astragalus shows the feature pointed out by Shattock and Parker of an obliquity in the neck, the

the axis of the trochlear surface forming with the axis of the neck an angle of about 40°.
The articular surfaces are also of great interest. The upper or trochlear surface of the body is not limited in front by a straight margin from side to side at the junction of the body and neck of the bone, but by a curved outline so that two horns project forward on either side on to the neck. The internal of these is continuous with an elongated pyriform area for the internal condyle, and the inter-vening area, although not covered with articular cartilage, is smooth. These surfaces correspond to those described by Thompson in the tibiæ and astragali of some of the lower races. The surfaces are also identical with those described by Havelock Charles in the tibia and astragalus of the Punjabi, and also described by him in the fœtal and infantile specimens of the same race, and it is of peculiar interest to note that the British infant resembles in the three osseous characters, (1) the head of the tibia: (2) lower end of tibia, and, (3) neck of astragalus, its fellow of a different race, while the adults of the two races are quite distinct from one another in

in these characters.

It only remains to carry the same examination a little further and to investigate in the same manner the fœtal and infantile anthropoid.

It is known that the face and head of the infant gorilla resemble those of the infant negro as far as external characters go, and it is just possible that in their lower extremities a similar resemblance in the bones might be detected. From my observations it would appear that the human infant is born with the limb skeleton approaching the ape but with the brain ~~approaching the~~ characteristically human in complexity of convolutions and relative weight.

As a summary the following is a statement of my conclusions:-

(1) At an early age the proportionate length of the bones is very different from what it is in the adult.

(2) As development proceeds the adult proportions are gradually assumed, but even at birth the general tendency of the proportions as shown by the indices approximates towards that found in the apes.

(3) The relative lengths are never similar to what is found in any one race of mankind; resembling one race- e.g., the Esquimaux- in one respect but differing from it in another

(4) The configuration of the skeleton of the lower limb presents some striking divergences from that of the adult and resembles in some respects the skeleton of the apes and of some prehistoric people.

(5) This peculiar configuration is not adapted to the erect attitude of the adult and becomes modified even before physical forces can come into play.

(6) These differences may be ascribed either to a mechanical cause- intra-uterine attitude- or to a morphological cause. Further information is still required before this question can be settled.

David Waterston.

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Age	Sex	Humerus	Radius	Rad. Hum. Index	Ulna	Femur	Fem. Hum. Index	Tibia	Tibio-Fem. Index	Intermembral Index	Fibula
6 w.	M.	7	5	71							
8 w.	M.	12	10	83.3		13	92	9.5	73	97	
9		15.5	12	78							
10		15.7	12.5	79							
3 mo.		23	17.7	76.9	18.5	25	92	17.5	70	96	15.7
3½ "	F.	36.5	27	73	30	39.6	92	29.5	75.6	92.6	28.6
3-4	M.	39	29	74	32	44	88.6	35	79.5	86	30.5
"	M.	39	29	74	33	44	88.6	35	79.5	86	31
"	F.	40	31.3	78	33	44	90.9	36.5	82.9	88.5	31
5 twin	M.	41	32	78	33	44.5	92.1	36	80.8	90.6	34
4-5	F.	48.5	37	75	41	55	87.2	46	83.6	84.6	43
"	M.	51	39	76	44	59	86.4	47.9	81.1	84.1	45.6
"	M.	52	39	75	44	59	88.1	47.9	81.1	85.1	45.6
5	F.	49	38	77.5	43	56	87.5	46	82.1	85.2	43
"	F.	50	39	78	43	57	87.1	46	80.7	86.4	41
5½"	F.	55	42	76.3	48	62.7	87.7	49	79	86.8	47
6"""	F.	60.5	44.5	72	51	73	82.8	59	80.8	79.5	54
	M.	64	51	79.6							
	F.					76.5		62	81		58
7-8	F.	65.2	48	73.6	53	76	85.2	63	82.8	80.7	60
" 8	F.	68	50	73.8	57						

Age	Sex	Humerus	Radius	Rad. Hum. Index.	Ulna	Femur	Fem. Hum. Index.	Tibia	Tib. Fem. Index.	Fibula	Intermembral Index.
9	M.	72	55	76.3	61	87	82.7	70	80.4	62	80.8
$8\frac{1}{2}$	M.	74	57	77	62						
$8\frac{1}{2}$	F.	73	56	76.5	62	88	82.9	72	81.8	69	80.6
9	M.	84	63	75	72	101	83.1	82.6	81	76	80
9	M.	84	64	76.1	73	101	83.1	82.6	81	76	80.6
9	M.	84	63	75	72	100	84	83.1	83	76	80.2
9	M.	85				104	81.7				
9	F.	88	70	79.5	76	103	85.4	90	87	85	81.8
9	M.	84	66	78.5	74	102	82.3	85	83.3	79	80.2
9	F.	90	66.2	75.5	77	108	83.4	88	81	82	79.6
Post Natal											
3 mos.		97	73	75.2	81	121	80.1	94	77.6	91	79
		98	73	74.4	81	121.7	80.1	95	77	92	79
1 year		111	82	73.8	90	142	78	115	80	112	72.5
27 mos.		133	94	70.6	101	174	76.4	133	76	128	73.9
		133	93	69.9	100	173	76.8	133+	76	128	73.9

Hand and Foot.

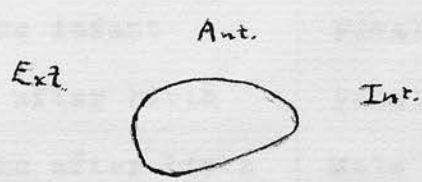
	3 mos.	$3\frac{1}{2}$	$4\frac{1}{2}$	5	8	9	9	3 mos.
METACARPAL of index finger.	7.3	8.3	12	11.6	18.6	22	22	25
PHALANGES of " "	10.2	11.6	15	15.6	25	28	30	31
METATARSAL of second toe	8.2	7	12	11	21.5	18	25	27
PHALANGES of " "	6.5	7	12	10	15.6	13.7	19	19.5

HEAD of HUMERUS and LENGTH of SHAFT.

Age	5 mos.	7	8	9	9	9
Sex	M.	F.	F.	M.	M.	F.
DIAMETER of HEAD	8	12	11	16	$16\frac{1}{2}$	17
LENGTH of SHAFT	50	60	60.5	80	84	84

Age	Sex	Extreme Length	Diameter of Head 1) Antero posterior	2) Vertical	Head, Neck and Great Trochanter	Condyles. Transverse Diameter	Antero posterior, outer	" " inner	Diameter of Head, = 1. Bicondyloid diameter is.	Ratio of Head to length of shaft.
9	M.	92.5	13	13	23	25	17.	14	1.9	7 +
8	F.	88	11	11	19	19	15.	14	1.7	8
9	M.	100	15	15	27	28	20.	19	1.8	6 +
8	F.	82	$11\frac{1}{2}$	$11\frac{1}{2}$	20	20	15.	14	1.9	7 +
9	F.	108	$17\frac{1}{2}$	$16\frac{1}{2}$	28	$29\frac{1}{2}$	21.	19	1.6	6 +
9	M.	99	15	15	26	$26\frac{1}{2}$	19.	18	1.7	6 +
6	M.	62	$7\frac{1}{2}$	$7\frac{1}{2}$	16	15	11.	9	2.1	8 +
5	M.	57	$7\frac{1}{4}$	$7\frac{1}{2}$	$13\frac{1}{2}$	13	10.	$9\frac{1}{2}$	1.8	8 −
5	M.	59	$7\frac{1}{4}$	7	15	15	11.	10	2	8 +
4	F.	$44\frac{1}{2}$	6	6	11	$11\frac{1}{2}$	$7\frac{5}{4}$	$7\frac{5}{4}$	1.8	7

Table of Measurements of Femora at different ages.



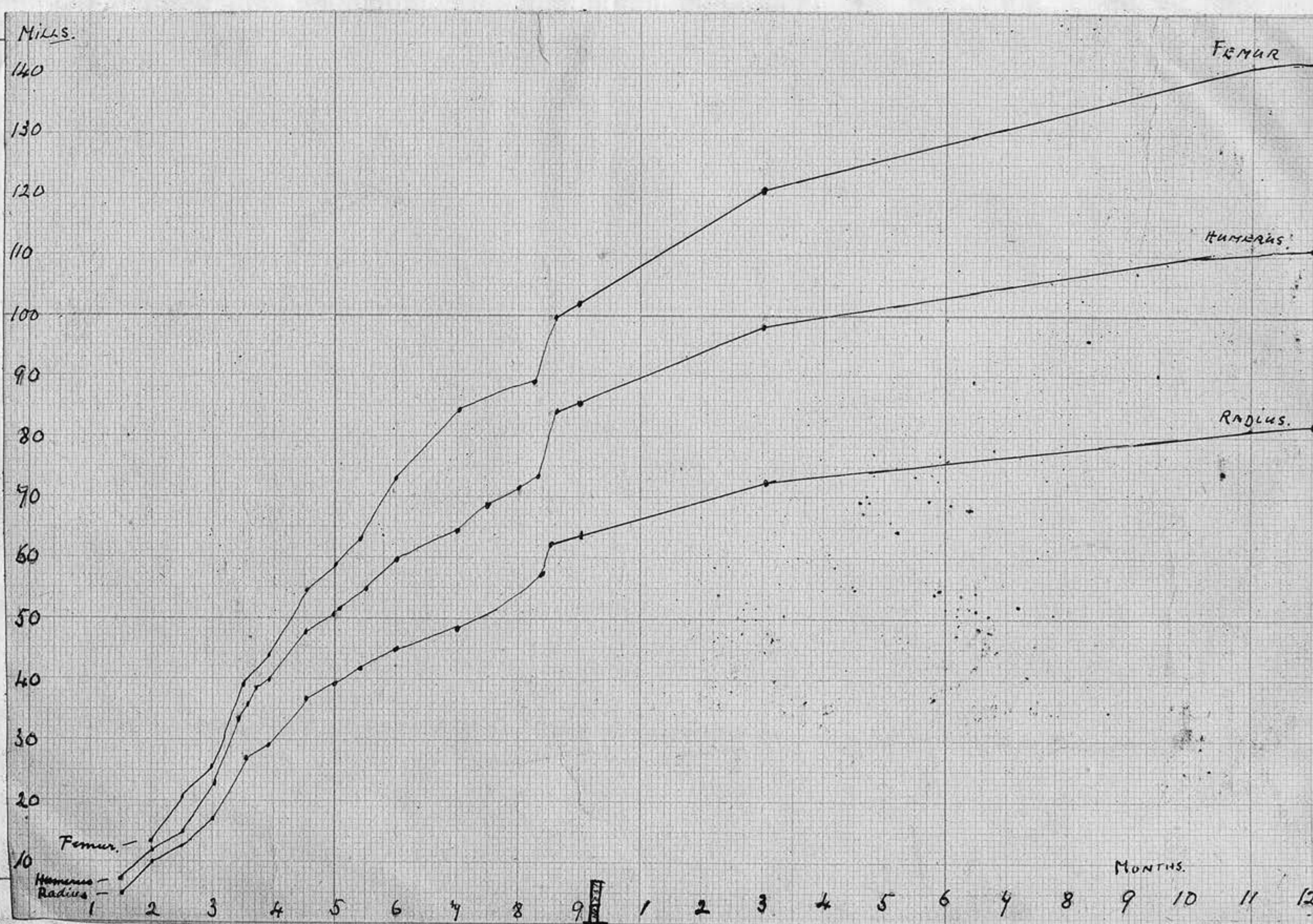
T.S femur, 27 months.

FEMUR.

Size of the angle of the neck and shaft at different ages.

(1)	3 months		135°
(2)	$3\frac{1}{2}$ "		129°
(3)	4 "	Female	126°
(4)	5 "	Female	132°
(5)	5 "	Male	134°
(6)	5 "	Male	131°
(7)	7 "	Female	128°
(8)	8 "	Female	124°
(9)	8 "	Female	127°
(10)	9 "	Male	132°
(11)	9 "	Male	122°
(12)	9 "	Male	120°
(13)	9 "	Male	124°
(14)	9 "	Male	125°
(15)	9 "	Female	127°

(16)	3 months infant	Female	125°
	1 year after birth	Female	120°
	27 months after birth	Male	125°


MILLS.
140
130
120
110
100
90
80
70
60
50
40
30
20
10
FEMUR
HUMERUS.
RADIUS.
MONTHS.
Femur —
Humerus —
Radius —
1 2 3 4 5 6 7 8 9
1 2 3 4 5 6 7 8 9 10 11 12

All the Photographs represent the natural size of the objects, except when otherwise stated.

PHOTO I.

On the observer's left, the humerus and radius at eight weeks.

On the right, humerus, radius and ulna at nine weeks.

The head of the humerus is clearly defined from the region of the tuberosities by a groove, and the length of the radius in relation to the humerus indicates a high radio-humeral index.

PHOTO II.

Limb bones at two and a half to three months. The humerus exceeds the tibia in length, and approximates to the length of the femur.

The radius and ulna have a length nearly equal to that of the tibia fibula. The neck of the femur forms rather a wide angle with the axis of the shaft, and the constriction at the base of the head is definite.

PHOTO III.

Limb bones at three months.

Shows that:-

(1) The humerus exceeds the tibia in length.

(2) The humerus and femur are of such a length that the femoro-humeral index will be high.

(3) The humeral head is rotated backwards to a considerable degree.

(4) The head of the femur is not rotated forwards to any extent, and the head is marked off from the neck.

(5) The length of the radius is not so great in relation to the humerus as in the earlier specimens.

(6) The fibular malleolus exceeds the tibial in length.

I

II

III

PHOTO IV.

Limb bones at three and a half months. (Intra uterine)

Note the growth in size, compared with No. III.

PHOTO V.

Limb bones (Male) at five months. (Intra uterine)

The humerus and femur maintain the same relative length.

The head of the humerus is still prominent, and in this specimen, does not display much rotation.

The radius and ulna are well seveloped, and have still the greater proportionate length than in the adult.

The humerus exceeds the tibia in length, and the fibular malleolus is larger than the fibular.

IV

V

PHOTO VI.

Another specimen about same age, showing more marked inequality in the length of the malleoli, the fibular being the larger.
The smoothness of the anterior surface at the lower end of the humerus is distinctly seen and also the cylindrical character and regularity of outline of the shaft.
The head of the femur is marked off from the neck, and the shortness of the neck is noticeable.
The shaft of the bone is almost vertical when supported on a flat surface by the condyles.

PHOTO VII.

Limb bones of female, about five months.
Shows inequality of humerus and tibia, and relative shortness of femur, and the whole outline of the bones is very typical of the condition at this stage.
The lower end of the shaft of the humerus is smooth on the anterior aspect.

PHOTO VIII.

Radius and ulna from full time specimen.
The well-marked curvature, and the relative width of the shaft of the radius is noticeable.
The bones have a more "muscular" appearance than the other parts of the skeleton of the upper limb.

VI

VIII

VII.

PHOTO IX.

Four bones from a nine months male.
In this the tibia slightly exceeds the humerus in length.
The articular surface on the anterior aspect of the lower end of the tibia is present in this specimen, but is small and not so distinctly seen as in some of the others.

PHOTO X.

Humerus and femur in nine months male.
Shows very well the distinctive characters of the fœtal bones at this age, especially the larger articular ends and the comparatively slender shafts.
The length of the humerus is still large in comparison with that of the femur, and the head of the bone is rotated backwards, and that of the femur rotated forwards.
In the femur the angle of the neck and shaft is very similar to that found in the adult, and the great trochanter is small, and the neck short.
The trochlear surface is well formed, but still rather flat.
The articular surface head does not merge upon that of the neck anteriorly.

PHOTO XI.

Three months after birth. Reduced in size.
The relative length of the bones is approaching that of adult life, the tibia being longer than the humerus, and the humerus shorter in proportion to the femur than has been usually the case up till full time.
The fossæ at the lower end of the humerus in front are much more distinct.
The tibial malleolus is a little longer than is represented.
The retroversion of the head is less marked.

1x

x

x 1

PHOTO XII.

Five femora (reduced from natural size), one at five months, two at seven months and one at nine months, and one at three months after birth, to show the shape of the trochlear surface, anteriorly, and the depth of ~~the intercondyloid notch~~ its lower aspect. Shows also the size of the angle of the neck and shaft at these ages.

The trochlea reaches higher up on the outer surface in the last largest specimen than in the others, and the intercondylar notch is more acute.

PHOTO XIII.

The upper ends of four full time femora.

In the three bones to the right, the character of the junction of the head and neck is as described in the text, and shows a sharp line of demarcation.

The specimen to the left has this feature in a less distinct form.

XII

XIII

PHOTO XIV.

Pelvis and lower limbs at five months. Male. The ligaments have been left in position, but all the muscles removed from the thigh and leg.
The joints are quite flexible, and the attitude is that which the limb takes up when the spine is suspended by a hook.
The attitude is one of flexion and abduction, and rotation out at the hip, considerable flexion of the knee, and inversion of the foot, with slight extension at the ankle.

PHOTO XV.

Five femora, at three, five, seven, eight and nine months, to show the gradual rotation forward of the head from the transverse axis of the condyles.

PHOTO XVI.

The lower ends of five femora at the ~~ages of~~ fi~~ve~~fth, seven th ~~and nine~~ months of intra-uterine life at full time, ~~and~~ & at the third ~~of three~~ month~~s~~ and one year of extra-uterine life, to show the size of the two condyles, and the prolongation of the articular surface on the internal condyle on to the upper aspect.

The width of the shaft at the lower end is noticeable, and is associated with a diminution in the antero-posterior measurement.

The inner condyle is to the right side in each case.

PHOTO XVII.

Four femora at full time.

This photograph shows the width and shallowness of the trochlear surface, the width of the intercondylar notch, and the relative length of the two condyles, the inner being the shorter.

XVI

XVII

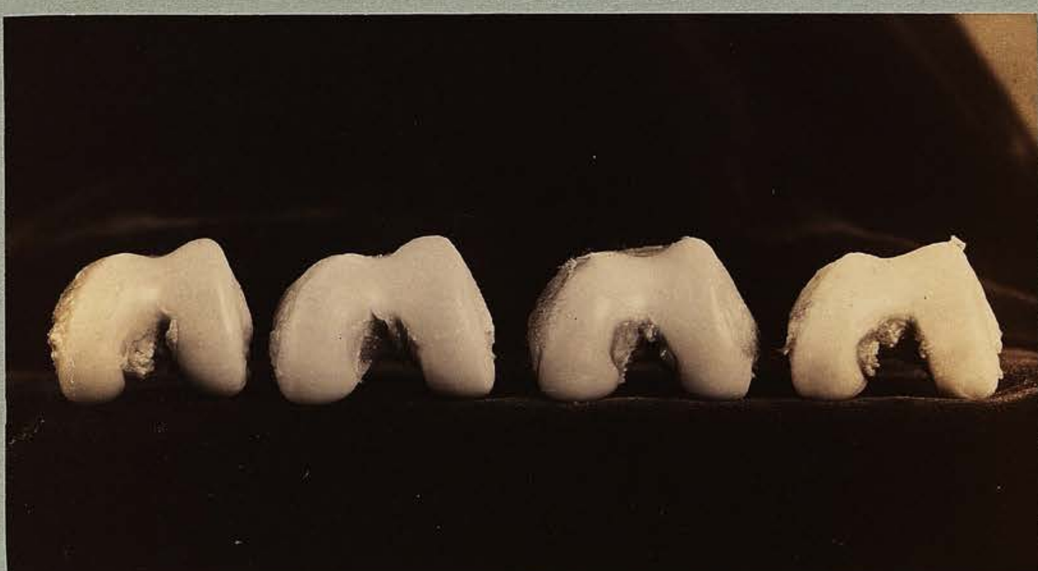


PHOTO XIX.

Four bones from the lower limbs of a female at seven and a half months.
The retroverted condition of the head of the tibia in the middle is very striking.
The spherical character of the head of the femur, its limitation from the neck, and the elongated spindle-shaped character of the shaft are very typical of the conditions found at this stage.

PHOTO XX.

Three bones from a full time specimen.
The greater length of the external malleolus is evident.
There is a small but distinct articular facet on the anterior aspect of the inferior extremity of the tibia.
The shaft of the femur has still the character described in the previous specimen.

PHOTO XXI.

A series of tibiæ and fibulæ at three, five, five, five, and seven months, from left to right, to show the charactersof the condylar surfaces from the third month onwards.
The characters described in the text are well seen.

XIX

XX

XXI

PHOTO XXII.

Tibia, fibula and astragalus at nine months, showing the additional facets and the angle which the axis of the body makes with that of the head and neck.

PHOTO XXIII.

A series of tibiae at nine months, and at one year after birth.

Characters of condylar surface well seen.

Taf. II

Taf. III

PHOTO XXIV.

The head of the left tibia and fibula, with the shaft vertical, at one year and at two years and three months.

It will be noticed that there is a great similarity between the two out lines.

The external condylar surface is still slightly convex, but the oblique direction of the surfaces has given place to a more ~~vertical~~ horizontal direction.

The retroversion has almost entirely disappeared even in the younger specimen.

PHOTO XXIV.

Lower end of tibia and fibula and astragalus at two years and three months.

Contrasting the condition here with that in the last photograph it will be noticed that the additional articular facets on the anterior aspect of the lower end of the tibia, and the prolongation of the trochlear surface on to the neck of the astragalus are still present.

The astragalus, however, has the body and the neck much morein the same line than is the case at birth.

XXIV.

XXV.